

CONTRIBUTION TO A FURTHER KNOWLEDGE OF
AUSTRALASIAN OLIGOCHÆTA.PART I. DESCRIPTIONS OF TWO SPECIES OF A NEW GENUS OF
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(Plates xxix.-xxxi.)

The present paper deals with a new genus (including two species) of freshwater Oligochæta belonging to the family *Phreodrilide*. The specimens were found in association with the large crayfish (*Astacopsis serratus* Shaw), and I am led to regard their occurrence in that particular way not as a mere accidental one, but rather as one of constant association. These Oligochæta are evidently not readily visible on the surface of the crayfish, and very probably occur in association with the eggs of *Temnocephala* which is found so abundantly on *Astacopsis*. The first evidence of the presence of these minute Annulates in association with the crayfish is usually afforded by the detection of small worms among the eggs of *Temnocephala* when these structures have been removed from the crayfish after the latter has been subjected to the action of some killing-fluid.

The specimens of one species were obtained in the Bulli district, and were labelled "surface of *Astacopsis*." For these I am much indebted to Professor Haswell. The second species I obtained when on a collecting tour in the Gosford district. Some large specimens of crayfish which I obtained, when placed in 10% formalin, yielded numerous individuals.

This accentuates my opinion that the genus which I have instituted is very probably to be found in constant association

with *Astacopsis serratus*—an occurrence somewhat analogous to that of *Temnocephala* on that Crustacean genus. This, I believe, is the only known case of such an association as regards the Oligochæta except in the family *Discodrilidae*, in which we find *Branchiobdella* on the gills, etc., of *Astacus fluviatilis*, and *Bdellodrilus* on *Cambarus*; but in these genera there is a state of true parasitism accompanied by special modifications in accordance with it, so much so in fact that these forms were once regarded as belonging to the Hirudinea. The peculiar manner of occurrence of this new genus lends some interest to it, inasmuch as one reasonably expects the possibility of the existence of some features of special significance in an organism which has adapted itself to such conditions.

At first I imagined cursorily I had an Enchytræid genus, on account of the position of the essential genital organs and their pores; but the character of the setæ, on detailed examination, and the posteriorly situated spermathecae, place it certainly among the *Phreodrilidae*.

ASTACOPSIDRILUS, gen.nov.

Resembling *Phreodrilus* Beddard, and *Phreodriloides* Benham, in general as regards external characters and anatomy, but differing from them in having spermathecal structures in segment xiv., almost devoid of musculature, without direct openings to the exterior but communicating with ovisacal structures in segment xiii.

ASTACOPSIDRILUS NOTABILIS, sp.nov.

The specimens were fixed in micro-nitric solution. The results of my investigations were obtained by the examination of entire specimens stained with hæmatoxylin and mounted in canada balsam, together with transverse and longitudinal series of sections similarly treated and counter-stained with eosin.

Body.—The body consists of fifty-three segments, and measures 5.5 mm. in length; and 0.65 in breadth in the middle region of the body, 0.30 at the anterior extremity, and 0.23 at the posterior end. The greatest body-thickness is to be found in the region of

segments x.-xiv., these metameres increasing in diameter as they approach segment xii. The area of segments xii.-xiii. constitutes a well marked girdle, the clitellar region being confined to these segments. The line of division between these two segments is not distinct, and even in longitudinal sections the septum sometimes appears to be absent, although the ganglionic aggregations in the ventral nerve-cord make the distinction clear enough. In the region of the body anterior to segment x., the lines of division between the various metameres are marked by perfect grooves, but in the postclitellar region the lines of division become less and less important as they approach the posterior extremity of the body. The prostomium is semicircular in contour, measuring 0.12 mm. in the killed specimen from the anterior extremity to the groove separating it from the buccal segment.

Setæ.—Ventral setæ are absent in the first or buccal segment as in Oligochæta in general. No traces of them could be found in the clitellar region (segments xii.-xiii.) after careful examination of specimens treated in various ways. In all the other segments there are present two fascicles, which are situated in the latero-ventral regions of the body, each containing a pair of setæ. The setæ are exceedingly small in the anterior region, but gradually increase in importance, so that behind the clitellum they become very well developed.

The paired setæ of the latero-ventral fascicles are sigmoid in shape, with no feebly expressed nodulus, those in the posterior regions being more strongly curved than the setæ of the anterior regions of the body. In each bundle one of the setæ exceeds the other in length, the respective measurements being 0.08 mm. and 0.07 in the middle region of the body, the shorter one being slightly more strongly curved at its free extremity. In the anterior region of the body the setæ become shorter and shorter as they approach the buccal segment. One seta in each bundle has a simple extremity, the other possessing a notch on the convex side of the curved portion near the free extremity.

The dorsally situated setæ occur in segments xxxi.-xliii., are long and slender, and for some time escaped detection in the

examination of an entire specimen, whereas the ventral setæ were easily and readily made out. They measure 0·13 mm. in length, but vary much in shape in different segments, some being in the form of a much elongated S, or rather resembling the curved capilliform setæ of *Phreodrilus subterraneus*; others being straight, but all gradually becoming strongly attenuated from the base towards the very fine free extremity. The portion of each seta hidden in the body is straight and of uniform thickness. The region of the body in which dorsal setæ are seen in entire specimens does not actually mark out the limit of the area of occurrence of such, inasmuch as I have found dorsally situated setæ completely enclosed in setigerous sacs, even in the anterior region of the body, but they do not project beyond the surface, and, judging from their strength of development, are possibly disappearing.

The male pores are situated in the anterior region of segment xii., immediately behind the septum forming the anterior boundary of that segment. The cells in the neighbourhood of the pores are of a glandular nature, certain of them being pyriform and taking a deeper stain than contiguous cells. The pores cannot be made out in the entire specimen, but by means of longitudinal sections they are made readily visible.

The female pores are situated at the anterior extremity of segment xiii., immediately behind the septum separating segments xii.-xiii.

The spermathecal pores have disappeared, but in the position in which one would expect to find them, viz., on the ventral surface of segment xiii., there is present, on the right side of the body, a solid strand of glandular cells with deeply stained nuclei, connecting the lower spermathecal sac with the ventral body-wall in the posterior region of that segment. In the immediate vicinity of this structure there is present a pair of setæ which differ in no wise from the other latero-ventral setæ.

The clitellum is in the form of a cingulum round segments xii. and xiii., as mentioned previously, the ventral region being much thicker than the dorsal.

Digestive system.—The pharynx is a thick-walled chamber extending from the buccal cavity in the first segment to the posterior region of the fourth segment. It is somewhat compressed laterally, and the antero-dorsal portion of its cavity is produced into a pocket which is sent off anteriorly and obliquely towards the dorsal surface. The formation of this pouch is due to the presence, in the middle of the anterior boundary of the pharynx, of a mass containing an abundance of nerve-cells which become continuous with the posterior portion of the brain. Judging from its constitution one would be inclined to regard this structure as a sensory or tasting organ. The wall of the pharynx consists of very tall columnar cells provided with very long cilia. External to this epithelium is a layer of longitudinal muscle-fibres connected with the body-wall above and below, and with the prostomium.

The œsophagus extends from segments iv.-xiv., in the form of a sinuous tube whose contour shows only a very slight constriction in the region of the septa. On entering segment xi., it becomes displaced from the central position which it has occupied so far in the body, towards the ventral body-wall owing to the great mass of developing spermatozoa which are present in that segment. It maintains this position throughout its further extent, and, in segment xiv., rises to a more central position in the body-cavity, and passes into the intestine which commences in segment xv. The portion of the intestine situated in segments xv.-xviii., inclusive, is constricted so as to form a well pronounced pouch in each of those segments. Behind this, the pouches become less and less distinct. The intestine contains an abundance of foreign material, diatom valves, etc. The digestive canal is provided throughout with exceedingly long cilia. The wall of the œsophagus differs from that of the intestine in being much folded, and in having an epithelium of slightly taller cells. The intestine has its wall covered by a plexus of bloodvessels, and this no doubt is connected with the digestive function.

Vascular system.—The attempt to make an entire reconstruction of the blood-vascular system is attended with great difficul-

ties, and the assistance gained from the study of an entire specimen has been of little use in making the following brief notes. One finds that this system suffers much damage when the sections are injured in the process of cutting, on account of the presence of siliceous material in the digestive tube, and especially so as the vessels appear to have in their walls something of a chitinous nature, and the tortuous nature of the vessels increases the difficulties attendant on a detailed reconstruction of the system, the investigation of which would no doubt be much facilitated by observations made on living specimens.

There are present throughout the body a dorsal and a ventral longitudinal vessel, the former much the larger and pursuing an undulating course along the mid-dorsal line of the digestive canal; the latter lying immediately above the ventral nerve-cord, and pursuing a straight course. The dorsal trunk is locally dilated in each of segments v.-x., and is constricted at each of the septa separating these segments, so that, in an entire specimen, it appears as a linear series of swollen loops, one in each of these segments, above the digestive tube. In the first three segments it is much narrower and pursues a straight course, but behind these it follows a tortuous path, turning on itself in a sigmoid fashion in each segment. In segment x., it turns towards the ventral vessel in association with the deflection of the œsophagus in this region, so as to lie in the centre of the body-cavity in segment xi. In segment xii., it rises again to a more dorsal situation as before. Immediately in front of the septum separating segments i. and ii., it turns downwards to run under the brain between that structure and the antero-dorsal wall of the pharynx, emerging again in the midline on the antero-ventral aspect of the brain between the œsophageal connectives, and immediately bifurcates. The branches thus formed run off at right angles to the stem, each in company with an œsophageal nerve-connective; eventually they unite to form the ventral vessel in segment iii., that is the segment behind that in which lies the subœsophageal ganglion formed by the junction of the œsophageal connectives.

Commissural vessels of an undulating character connecting the dorsal and ventral bloodvessels were made out in segments iv.-x., inclusive, and from segment xv., backwards. In the postclitellar region commencing in segment xv., the pouches of the intestine are found to be covered by a network of fine vessels in connection with the commissural vessel; and this is specially interesting as no such plexuses are to be found on the portion of the digestive tube anterior to this. Hence an additional character is found as an assistance in the differentiation between the œsophagus and intestine which is thus clearly seen to commence in segment xv.

In segment xii., there is found, occupying the greater portion of the body-cavity, a mass of a granular nature which takes a stain with eosin similar to that of the bloodvessels and which, in the unstained state, has the same appearance as the bloodvessels. The thought occurs to one that this mass of granules represents a glomerular structure; but I am at a loss to understand its significance, since, both in transverse and longitudinal sections, the granules under high powers of the microscope appear to be quite free and separate, no mutual connection being made out between them. Further, I have observed that the granular nature of the epithelial cells lining the spermathecal sac is due to the presence, in their cytoplasm, of granules similar to those above-mentioned; and as the ducts from these sacs run forwards to the posterior wall of segment xii., it is quite possible that some relation exists between these granules, and that the mass of material present in segment xii. has been derived from the epithelial lining of the spermathecal sacs.

A reconstruction of the blood-system made from a study of transverse and longitudinal sections is to be seen in Pl.xxx., fig.15.

Excretory system.—Nephridia occur in pairs, as very complex coiled tubes similar to those of the *Tubificide* in general, in most of the segments. No traces of them can be found in the first six segments, nor in segments xi., xii., xiii., in which latter lie the essential reproductive organs and their ducts. No distinct internal funnel or external pores were made out. In examining

transverse sections one would be inclined to regard the nephridia of segments vii.-x., as being in the form of one much-coiled, continuous tube as is found to be the condition of the pregenital nephridia in species of *Phreodrilus*. On examining longitudinal sections, however, it is found that each of these segments has a pair of nephridia quite distinct from those in the segments anterior and posterior to it; but the nephridia on each side occupy nearly the whole distance between the anterior and posterior septa of a segment, so that the coils of any one nephridium on each side lie in close proximity to the funnel-region of the nephridium which passes through the septum from the next posterior segment. The almost unavoidable obliquity of transverse sections (however slight it may be) is enough to show, in one section, traces of the nephridia of at least two adjacent segments, but there is certainly no continuity as regards the nephridia of segments vii.-x.

In his description of *Phreodriloides*, Benham remarks of the nephridia that "they seem to be asymmetrically disposed, for the first organ lies on the left side of segment vi. Those of the following segments are also confined to the left side; that in segment x. is on the right side; and further back I see only one in a segment" (*l.c.* p.262).

This asymmetry in *Phreodriloides* finds its parallel in *Astacopsidrilus* in a corresponding complete disappearance of the rudimentary spermathecal duct of one side, and not in the disappearance of the nephridia of any one side.

It is rather an interesting fact that the pregenital nephridia in *Phreodriloides* Benham, and *Astacopsidrilus* mihi—two genera belonging to New South Wales—are apparently not united to form a continuous tube, whereas such is the case in *Phreodrilus albus*, *P. Kerguelenensis*, *P. niger*, and probably also, Benham thinks, in *P. lacustris*.

Again, *Phreodriloides* shows an asymmetry in regard to the pregenital nephridia, and these are quite absent, apparently, in *Phreodrilus subterraneus*. *Astacopsidrilus* agrees with *Phreodrilus Kerguelenensis* in that the pregenital nephridia occupy

segments vii.-x., and Benham describes pregenital nephridia as being present in segments vii. and x. in *P. lacustris*.

Nervous system.—The brain lies in the cavity of the buccal segment in close apposition with the antero-dorsal wall of the pharynx, being directed obliquely so that its ventral portion projects slightly into the prostomium. It is in the form of a biconvex mass, the anterior boundary being strongly convex, the posterior surface only slightly so. From the ventral extremity there pass round the buccal chamber, on each side, two stout strands of neural material—the œsophageal connectives—which unite in the second segment to form, together with the mass of nerve-cells, the subœsophageal ganglia of the ventral nerve-cord. These connectives of neural cords lie in close apposition with the anterior wall of the pharynx, enclosing between them the narrow buccal cavity; and each is accompanied by one of the blood-vessels formed by the bifurcation of the dorsal vessel. A massive structure containing an abundance of nerve-cells arises from the posterior surface of the brain, and projects into the cavity of the pharynx, as mentioned previously. Neurocordal substance is sent off, in the form of two strands, to supply the prostomium and what corresponds to an upper lip.

Reproductive system.—Male organs: the testes are paired structures attached to the anterior wall of segment xi. The cavity of this segment is filled with a mass of developing spermatozoa formed by the breaking up of the testes. This mass consists of ripe spermatozoa together with aggregations of rounded cells representing developing spermatozoa, and resembling closely similar aggregations in the *Enchytræideæ*. Outside this segment no spermatozoa are visible. In an examination by transmitted light of an entire individual, this mass of spermatozoa is very evident as giving rise to an opacity which occupies a great part of the body-cavity lying dorsal and lateral to the digestive tube, which is thereby displaced towards the ventral body-wall, and practically surrounded by the mass, except on the ventral aspect. Among this mass of developing spermatozoa are pear-shaped bodies, probably sporozoa(?).

The funnel of the spermiduct projects from the anterior side of the septum between segments xi. and xii., for a considerable distance into the cavity of the former segment. The funnel is provided with exceedingly long cilia, and is readily detected in longitudinal and transverse sections by the very deep stain it takes after treatment with hæmatoxylin. This deep colouration, one is inclined at first to regard as being due to masses of long cilia in connection with the funnel. No similarly stained masses can be seen among the aggregation of developing spermatozoa in segment xi., beyond that connected with the mouth of the funnel. Further, one can readily distinguish the cilia in connection with the funnel under a high power, and these are not affected by the stain. For these reasons I am rather inclined to attribute the deep stain to the presence of something of a glandular nature in the mouth of the funnel, as is to be found in the *Enchytreidæ* (?). Professor Benham found the same appearance in *Phreodrilus lacustris*, but attributes it to masses of developing spermatozoa, which may possibly be the case in my specimens, although I have been unable to make out under high powers anything of the nature of spermatozoa in appearance. The spermiduct is a coiled structure of the nature of a nephridial tubule, which, after leaving the funnel, passes back from the septum separating segments xi. and xii., upwards into the cavity of the latter segment for a short distance, and then turns on itself to run eventually towards the posterior region of that segment, whence it returns on itself to open into the atrium.

The spermiducal gland is confined to the same segment, and consists of a simple dorsal moiety running vertically, parallel to the anterior wall of that segment, its free distal end being in close proximity to the dorsally situated ovary. At about the level of the spermiduct it joins the ventral moiety, which is thrown into a flat vertical spiral lying posteriorly to the vertical dorsal or anterior half. After one complete turn of the spiral is completed, the gland is joined by the spermiduct; and the common chamber or atrium thus constituted is continued in the spiral as a gradually attenuating tube to open into the penial

canal. The wall of the spermiducal gland consists of large truncately cuneate cells, with granular cytoplasm, each with a large spherical nucleus situated in its outer portion. No traces of musculature investing these glandular cells can be detected. The sections through this gland constitute the most prominent structures to be seen in sections through this region with the exception of the ovary. The penis consists of a pyriform body enclosed in a penial sac, which is continuous with the organ itself on the dorsal aspect in the region where the atrial canal passes into the penial canal. The cavity of the penial sac is pear-shaped, its neck-like portion opening on the exterior in segment xii., immediately behind the anterior septum of that segment. The sac is lined by a flat epithelium with spherical nuclei, and this is invested by circular muscle-fibres external to which is a peritoneal epithelium.

The wall of the penis itself is differentiated into three portions.

(1) An internal epithelium surrounding the very minute lumen. The cells of this layer much resemble those of the spermiducal glands, but are much smaller. They are squarish in shape, with spherical nuclei, and non-ciliated. They secrete externally a cuticular substance which stands out distinctly as a bright, highly refractive band investing the epithelium.

(2) A spongy mass consisting of a matrix in which are scattered muscle-fibres circularly or obliquely arranged, and external to this again isolated strands of longitudinal fibres.

(3) Columnar epithelial cells with centrally placed spherical nuclei.

Although the penis was not found protruded in any specimens, one may safely say, I think, that it can be.

In Pl. xxix, fig. 4, is shown the male efferent apparatus reconstructed from longitudinal sections.

In examining an entire specimen, one notices two large spermathecal chambers, circular in optical section, lying in segment xiv., one dorsal to, and slightly overlapping the other. In longitudinal sections it is seen that the ventral chamber is connected with the ventral body-wall, as stated previously, by a

strand of cells with spherical nuclei and granular cytoplasm. This strand passes from the antero-ventral margin of the chamber through the septum separating segments xiii. and xiv., into the cavity of the first of these, to be attached to the ventral body-wall of the posterior portion of that segment in the region of the posterior margin of the clitellum. Traces can be seen of a cavity extending into this mass of cells from the exterior for some distance, but the cells become confluent with the ventral spermathecal chamber without any extension of that cavity into that of the chamber. The nature of their cytoplasm, their arrangement in an epithelial fashion along the sides of a cavity corresponding to a lumen, and the attenuation of the epithelium of the spermathecal chamber in the vicinity of the junction of the cells with that chamber, make it quite clear that we have here a spermathecal duct which is tending towards disappearance. Further, the position of the duct, lying as it does in segment xiii., corresponds exactly with the position of the spermathecal aperture in those other members of the *Phreodrilidæ* which are provided with spermathecæ. The spermathecæ are lined by a single layer of large squarish cells whose outlines are very distinct. These cells somewhat resemble those lining the spermiducal glands, but differ in shape, and in the much more granular nature of their cytoplasm. External to this epithelium is a very scant and indistinct trace of delicate longitudinal muscle-fibres.

In an examination of an entire specimen, there is seen in the dorsal region of the much abbreviated segment xiii., in close proximity to the septum separating it from segment xii., a pair of funnel-like structures in which one can make out a central lumen separated by an epithelium. Each of these is continuous with a duct which runs downwards and obliquely backwards. Beyond this no further traces can be made out in the entire specimen.

In longitudinal sections it is found that each of these funnel-like structures opens into the dorsal side of a thin-walled sac attached to the anterior wall of segment xiii. These sacs are paired structures, each of which passes ventrally into an oviduct,

one on each side of the body. Following the course of the funnel-structures, it is seen that they pass into tubes which run towards the postero-ventral region of segment xiii., and eventually through the posterior wall of that segment to reach the spermathecal chambers. That which joins the ventral chamber passes into a wide tube, which is found to run vertically upwards, and become confluent with the postero-ventral portion of that chamber. The wall of the tube consists of epithelium of tightly packed, cuneate cells with a ventrally placed nucleus, this epithelium being surrounded by circular muscle-fibres much more strongly developed than in the case of the spermatheca itself. The spermathecal tube connected with the other funnel, after reaching segment xiv., in company with that connected with the ventral spermathecal chamber, passes round the posterior border of the lower spermathecal chamber, between the œsophagus and the anterior extremity of the intestine, to open into the postero-ventral margin of the upper spermathecal chamber. The spermathecal chambers each contain a fusiform mass, consisting of a linear aggregation of spherical bodies, and apparently representing spermatophores. At first one feels inclined to ascribe to these chambers the function of egg-sacs, and to interpret the masses of spermatophores as aggregations of ova. Sections, however, show clearly that they are not ova, and this evidence is assisted by the presence of a disappearing duct connected with the ventral chamber, and corresponding in position with the spermathecal duct of the *Phreodrilidæ*. Further, so narrow is the duct leading from these chambers to the funnel in segment xiii., that the passage of ova along them would be as impossible as that of the ova of *Nereis* through the nephridia. We have, then, in *Astacopsidrilus*, a unique character in connection with the spermathecal chambers, inasmuch as (1) they are tending towards fusion and the formation of a medial unpaired sac, due to the moving upwards of the spermatheca of the left side, and connected by a wide duct-like passage with the dorsal side of the spermatheca of the right side; (2) the absence of a passage communicating directly between these chambers and the exterior, and the entire absence of any

traces of a representative of the same in connection with the dorsally situated chamber of the left side.

Female organs.—The ovaries are present in segment xii., as a pair of pyriform structures attached by the broad end to the anterior wall of that segment in its dorsal region, and in close proximity to the free distal extremity of the spermiducal gland. Numerous masses of maturing ova are found floating freely in the cavity of that segment, and these show, in their development, a great similarity to those of the *Enchytreidae*.

In segment xiii., there is, in attachment to the anterior wall on each side of the body, a sac, mentioned previously, into which open the funnels of the spermathecal ducts. No communication between these sacs and the cavity of segment xii., could be detected, although it seems evident that it represents the egg-sac. Each sac passes ventrally into an oviduct, to open at the anterior end of segment xiii. The structure of the wall of the oviduct is essentially the same as that of the ovisacs, consisting of a flattened epithelium, external to which is a layer of longitudinal fibres.

As in *Phreodrilus subterraneus*, etc., it is evident that the spermatozoa and ova do not mature at the same time. One finds spermatophores present in the spermathecæ, and evidently derived as a result of copulation, inasmuch as the organism is provided with what must be a protrusible penis. No ripe ova, however, were found in segment xii., nor any trace of the same in the egg-sacs. As it appears that copulation does take place, the spermatozoa must be transferred from another individual to the oviducts, thence passing up through the egg-sac to the funnels of the spermathecal ducts, and thence backwards to the spermathecal sac, from which they are later transferred again to the egg-sac, when the ova are matured, so that fertilisation would readily take place in the egg-sacs.

ASTACOPSIDRILUS FUSIFORMIS, sp.nov.

This species is to be found very abundantly on the surface of *Astacopsis serratus*, occurring in the grooves of the carapace. It

shows affinities sufficiently close to *Astacopsidrilus notabilis*, and equally well those characteristic features which distinguish that new genus from *Phreodrilus* and *Phreodriloides*, so that I deem it worthy of specific rank only.

External characters.—The colouration is white. The body is spindle-shaped and in general outline not unlike a cigar. It reaches its greatest diameter in segments xii. and xiii., the region of the body between segments ix. and xv. being swollen so as to give rise to a bulging area which is of greatest importance in the clitellar region. Behind segment xv., the body gradually diminishes in diameter. In the anteclitellar region the body is slightly flexed so that the dorsal margin is convex from before backwards. Length 2·8 mm.; greatest breadth 0·6 mm.

The total number of segments is 46; the anteclitellar segments, as in *A. notabilis*, are longer than those of the postclitellar region, and the grooves separating them much more strongly pronounced.

The prostomium is obtuse, its anterior margin crescentic and separated from the buccal segment by a groove. The posterior third of the prostomium appears to be marked off from the anterior portion by a feebly expressed groove.

The clitellum surrounds the body as a cingulum in segments xii. and xiii.; and, although not by any means as readily visible in an examination of entire specimens as in the case of *A. notabilis*, yet it can be easily made out with the naked eye, especially with the assistance of more dense stain, and consequent differentiation of this part obtained by the use of hæmatoxylin or borax-carmin.

Setæ.—There are in all the segments, except the buccal, segment xii., and the last three segments, two fascicles of latero-ventrally situated setæ. Those of segment xiii., (absent in *A. notabilis*) differ in no wise from the corresponding setæ of other segments. These setæ are very minute in the anterior region of the body, but gradually become more important as they approach the clitellar region, behind which they show no marked further or stronger development until they reach the posterior third of the body. In this posterior region they become very

strongly developed as in *A. notabilis*. Each latero-ventral bundle contains two setæ which differ slightly from each other. Each is sigmoid, but in the one case the S is much more elongate (*f*), and the extremity faintly bifid or quite simple; in the other case the curve-contour is more typically S-like, and the extremity shows a distinctly bifid character due to the presence of a small tooth, and the consequent appearance of a notch on the convex side of the free end of the seta.

Dorsal setæ are present in all the segments, except the first two, segments xii. and xiii., and the last few segments, as a single row on each side of the body. They are capilliform, but show a faint sigmoid contour. The portion of each seta within the body-wall is of uniform importance, but beyond this the seta becomes attenuated strongly towards the fine free extremity, and this free portion of the seta shows the sigmoid character feebly. As in the case of the ventral setæ, the dorsal setæ are most strongly developed in the postclitellar region, and especially so in that portion which is comprised in the posterior half of the body.

Pores.—The male genital apertures are paired openings situated in the lateral region of the ventral surface of the anterior region of segment xii. The female apertures are paired, and open in the lateral region of the ventral surface of the anterior region of segment xiii., exactly in the middle of the clitellar region.

No traces of spermathecal apertures are to be seen, this condition representing the extreme shown by the tendency towards disappearance of traces of the same in *A. notabilis*.

Alimentary canal.—The buccal cavity extends upwards and backwards to the middle portion of the body in the posterior region of the buccal segment as a wide passage, sending off backwards a pouch (v-shaped in vertical longitudinal section) into the ventral region of that segment, ventral to the nerve-cord. It is lined by a nonciliated, flattened, stratified epithelium with spherical nuclei.

The pharynx extends from the anterior region of segment ii., to the posterior portion of segment v. The lumen of the portion lying in segments ii.-iv. is much wider than that in segment v., appearing in sections as squarish in outline. The anterodorsal region of the pharynx shows an extra thickening due to the development, or rather presence, of several layers of cells, the pharynx in general being lined by a single layer of cells. This thickening corresponds to the region of the pocket-like continuation of the pharyngeal cavity in *A. notabilis*. The buccal epithelium passes into that of the pharynx at the ventral extremity of the brain, which lies in close apposition to the pharynx. The epithelium consists of very tall ciliated cells, with slightly elongate nuclei. The cilia are much shorter than those of the corresponding cells in *A. notabilis*; they appear as a hazy unstained layer internal to the epithelium, so as to readily mark off the pharynx from the posterior portions of the alimentary canal. As the pharynx passes towards the œsophagus in segment v., it becomes suddenly much narrowed so that its lumen is reduced in diameter to about that of the œsophagus, or to one-third of that of the anterior portion of the pharynx.

The œsophagus is a sinuous tube slightly constricted at each septum and extending as far backwards as segment xiii. It lies in the central portion of the cœlome as far as segment viii., in which it is forced towards the ventral body-wall and so as to pass beneath the mass of developing spermatozoa in segment xi., rising again to its former central position in the posterior region of segment xiii.

The intestine, like that of *Plagiochæta* and *Pontoscolex corethrurus*, instead of being in the form of a straight tube, constricted to form a distinct pouch in each segment, as is the case in *A. notabilis* and other Oligochæta in general, is arranged in a spiral fashion. Its anterior portion has the form of a large U-shaped mass extending through segments xiv.-xviii. Thence it proceeds as a gradually attenuated spiral tube as far as segment xxxv., behind which it assumes the form of a straight tube showing a slight constriction at each septum.

Unlike that of *A. notabilis*, the ciliated region of the digestive tube is restricted apparently to the pharyngeal portion. The cells of the intestinal epithelium differ from those of the gullet in being much flatter, and, further, the epithelium itself is less folded. In sections, also, the presence of the plexus-like arrangement of bloodvessels on the wall of the intestine is another distinguishing feature between these two regions.

In the œsophagus are found great numbers of large uninucleate masses, fusiform and vase-shaped, produced into a long flagellate thread. Similar masses are to be found in the cœlome in the region of the middle portion of the œsophagus, and a few examples were noticed as far back as segment xii. These masses I have identified as a Dicystid Gregarinidaceous Sporozoon, and in every probability a member of the genus *Stylorhynchus*. All the individuals noticed conformed to the spermatozoon type. No traces of Sporozoa were to be found in this species in the mass of developing spermatozoa, but I noted in that mass, in *A. notabilis*, pyriform masses representing the psorosperms of a Myxosporidian.

Cœlome.—The septa are extremely thin and indistinct, so much so that, in certain regions, one has to rely on the ventral nerve-ganglia in fixing the position and limits of organs in the study of longitudinal sections.

Nephridia.—Pregenital nephridia occur in segments vii., viii., ix., and x. They are extensive structures, occupying a great part of the cœlomic space. No nephridial structures are present in segments xi., xii., and xiii. The first pair of postgenital nephridia occurs in segment xiv. The arrangement of the pregenital nephridia is similar to that of species of *Phreodrilus*, those of each side being united to form a continuous tube extending from segments vii. to x. The extreme tenuity of these organs in the present species renders the tracing of the same very difficult, and I was unable to detect either pore or funnel. The arrangement of pregenital nephridia in segments vii.-x., resembles that of *Phreodrilus Kerguelenensis*.

Blood-system.—I have but few notes on the blood-system in this species, owing to the imperfect manner in which one can

trace the vessels by sections alone. Traces of commissural vessels were found in all the segments, and in the postclitellar region, connected with these in each segment, is a plexus of vessels in association with the intestinal pouch. No marked "heart"-dilatations of the dorsal vessel could be seen.

Male organs.—No testes comparable with those of other Oligochæta could be seen, but the body-cavity of segment xi. is filled with a mass of spermatozoa. This mass is contained within a thin-walled sac, the presence of which is denoted by the regular appearance of the mass, in examining an entire specimen in canada balsam, and resembling exactly that seen in *A. notabilis*—that of a large unpaired sperm-sac.

The funnel of the spermiduct projects for some considerable distance into the cavity of segment xi., and is attached to the posterior wall of that segment. In longitudinal sections it appears as an elongated horseshoe-shaped structure, directed obliquely towards the dorsal body-wall. Its wall consists of a single layer of squarish cells, with deeply stained spherical nuclei, and is provided with very long cilia which project for some considerable distance into the cavity of segment xi., beyond the mouth of the funnel. This bunched mass of cilia is comparable to that in the funnel of *A. notabilis*, but, unlike that in the latter species, it does not take such a deep stain, which colouration I noted in the description of that species as being due to something of a glandular nature. The mass in this case is certainly true cilia, and not spermatozoa, filling the funnel, as they can be clearly seen to be continuous with its epithelial cells; and, under the highest powers, show none of the characteristics of spermatozoa.

The spermiduct is a fine intracellular nephridial-like tubule, which, after leaving the funnel, passes backwards and ventrally as a much coiled structure to join the spermiducal gland. The duct is much shorter than that of *A. notabilis*, and does not extend, in a horizontal direction, posteriorly to the spermiducal gland. In transverse sections passing through the region of the anterior part of the spermiducal gland, one sees the spermiduct cut across a great many times, and appearing as a complex nephridial tubule, in section.

The spermiducal gland is much simpler than that of *A. notabilis*, but is arranged in general on the same plan. It is in the form of an "l," the vertical portion being short and most posterior in position, leaning in the direction of the anterior wall of the segment but not projecting for any great distance beyond the base of the penis. The spermiducal gland, as a whole, lies on the inner side of the penis. After the junction of the spermiduct with the gland, the atrium consequently formed shows no great diminution in size or change in structure. This common chamber runs from the junction with the spermiduct, upwards for a short distance, and then turns posteriorly to the inner side of the penial sac, and passes into a tubule which enters the penis.

The spermathecae, which were found in the paired condition in *A. notabilis*, are here represented by a single structure which passes transversely across the body, dorsally to the alimentary canal, and consists of a dilated chamber at each lateral extremity, connected by a narrow passage. The fusion, which was indicated in *A. notabilis*, is here complete, but, unlike the former species, no asymmetry is indicated. The spermatheca passes, at the latero-ventral portion of each lateral dilated chamber, into a duct which runs down towards the ventral surface of segment xiv., and, after turning on itself in a short coil, passes through the septum separating segments xiii. and xiv. It then turns on itself to run obliquely upwards to a thin-walled sac, which is situated in the antero-dorsal region of segment xiii.—the ovisac—into which it opens. The general course of the duct agrees exactly with that of *A. notabilis*. The wall of the spermatheca consists of a single layer of cubical cells, with centrally placed nuclei and granular protoplasm. The wall of the duct consists of a single layer of cells, about eight completing the investment of the very minute lumen. There is probably a very faint circular musculature round this epithelium, but it is very indistinct.

Female organs.—The ovaries are situated in segment xii., but no organ could be seen *in situ*. Masses of detached ova were seen in the cavity of this segment. The oviduct agrees in character with that of *A. notabilis*.

Remarks.—Until the last few years, the genus *Phreodrilus*, founded by Beddard in 1891, was represented by a single species, *P. subterraneus*, and was regarded as an appendix to the family *Tubificidæ*. As quoted by Benham, “Michaelsen gave an extended interpretation to that genus so as to include the four species of South American worms originally placed by Beddard in a distinct genus, *Hesperodrilus*; this enlargement of the genus has been rendered necessary by the discovery of a freshwater worm in Kerguelen, which, in certain respects, bridges over the anatomical gap between the two genera as formulated by Beddard, just as it serves as a stepping-stone in the geographical distribution of the genus as now extended.”

In 1904, Benham described three new species of *Phreodrilus* from the New Zealand lakes, and, in 1907, he instituted a new genus, *Phreodriloides* of the same family, on a single specimen obtained from the Blue Lake, Mt. Kosciusko, by Prof. David and Mr. Hedley.

This extension of the area of distribution of the *Phreodrilidæ* is very interesting, and more so now, in the further extension of the same into more temperate regions and conditions in the Australian area. In connection with this family, the conditions of habitat of the various genera are of some value from a phylogenetic standpoint. *Phreodrilus subterraneus* was obtained in subterranean wells; *P. lacustris* was obtained in Lake Wakatipu, at a depth of 300 to 1,000 feet; and *P. mauiensis* in Lake Manapouri, at a depth of 150 to 500 feet. The locality of occurrence of the South American and Kerguelen Island forms is also of interest. *Phreodriloides* was obtained in the Blue Lake, Mt. Kosciusko, at a height of 6,000 feet above sea-level, in a depth of 35 feet, the temperature being 44° Fah. These facts, in conjunction with the peculiar condition under which *Astacopsidrilus* (gen.nov.) is found, would seem to indicate that the family is constituted by a number of forms which have had to migrate from the field of competition into surroundings and conditions more favourable for the preservation of forms which have found it impossible to carry on the struggle for existence under more

arduous demands. The conditions of habitat, the small number of forms constituting the family, together with the geographical distribution of the various genera and species, would seem to indicate that the *Phreodrilidæ* are the remnants of an old Antarctic stock, the representatives of which are now to be found under conditions comparable with those of the stalked crinoids of the deep sea. The family is generally regarded, phylogenetically, as an offshoot of the Tubificid stem; and, in many ways, as being intermediate between the *Tubificidæ* and *Lumbriculidæ*. "In *Phreodrilus*," according to Beddard, in his description of *Phreodrilus subterraneus*, "we get the first stage in the development of capilliform setæ, and the commencing reduction of one pair of spermiducts." In *P. subterraneus*, the sigmoid, unnotched, ventral setæ are quite different from those of Tubificids, and the same applies in the case of *Phreodriloides*, and *Phreodrilus Kerguelenensis* and *P. beddardi*. But in all other species of *Phreodrilus*, and in *Astacopsidrilus* species, the bifid type of the Tubificid seta is foreshadowed. The *Lumbriculidæ* have all setæ of the Lumbricid type, and these are, in some forms, of the bifid pattern definitely established in the *Tubificidæ*.

The posteriorly situated spermathecæ indicate also a connection between the *Lumbriculidæ* and the *Phreodrilidæ*.

Again, the position of the genital aperture in *Phreodrilidæ*, and the apparent glandular nature of the spermiducal funnel epithelium in *Astacopsidrilus*, may possibly signify a reversion towards earlier characters of some lower members of the group, e.g., *Enchytræidæ*. However, much assistance in this question might be very probably obtained by a study of the development of the forms.

In connection with the question of distribution, it is interesting to note that the *Lumbriculidæ* are, I believe, restricted to the Northern Hemisphere, and the *Phreodrilidæ* to the southern portion of the Southern Hemisphere.

In regard to the spermathecal structures, the new genus, *Astacopsidrilus*, is of special interest, inasmuch as it is intermediate between *Phreodrilus* and *Phreodriloides* in that connec-

tion. In *Phreodriloides*, no spermathecæ or spermathecal pores are to be found, but the male efferent apparatus is peculiar. In his description of that genus, Benham remarks:—"In all species of *Phreodrilus*, the spermatheca exists in the form of a long sac which extends through two or more segments, and opens near the anterior margin of segment xiii."

In *Phreodriloides*, the spermduct passes into the neck of a large muscular sac into which it opens. There is nothing of a glandular nature in the structure of the sac itself, or in association with it. The neck of this muscular sac opens into a penial chamber which, according to Benham, "appears to be an invagination of the epidermis, being lined by an epithelium which, over the greater part of the outer hemisphere, is similar to the epidermis; but the whole of the mesial surface of the wall, as well as the apex and part of the outer wall, is lined by a layer of tall glandular cells. . . . The idea occurs to one that, in *Phreodriloides*, the spermatheca has passed forwards into segment xii., and has become coincident with the male pore. But there is nothing analogous to such a fusion throughout the Oligochæta, and a more reasonable explanation is, that the atrium has become a reservoir for the spermatozoa, and that copulation does not occur and that the muscular sac (or 'autospermatheca') discharges its own spermatozoa on its own ova, during the formation of the cocoon."

The nature of the spermathecæ, with their ducts devoid of any direct communication with the exterior through spermathecal pores, and entering into connection with the ovisac-structures, would seem to render more possible the moving forwards of the spermathecal structures; or, at all events, to argue that the spermathecæ, as such, have really disappeared in *Phreodriloides* and an "autospermatheca" developed. In *Astacopsidrilus fusiformis*, the spermathecal ducts are exceedingly fine tubes; and the musculature, readily noticeable as a constituent of the wall of the same ducts in *A. notabilis*, is practically absent. Traces of what evidently was a spermathecal pore, comparable with those of species of *Phreodrilus*, were noted in sections of

the latter species; and the spermathecal duct in this region is much more strongly developed, as regards size and musculature, than the portion continued forwards from this region to reach the ovisac-structure. From this it seems certain that *Astacopsidrillus* has been derived from a Phreodrilan stock; and that, judging from the fact that *A. notabilis* shows, in the case of its spermathecae, a tendency towards fusion, and that this fusion is complete, and no traces of any spermathecal pore can be seen in *A. fusiformis*, the former is the older species.

It is noteworthy that in the two Australian genera of the family, *Phreodriloides* Benham, and *Astacopsidrillus* gen. nov., the variation of most significance with regard to *Phreodrilus* Beddard, is in connection with the spermathecae—structures which are of the greatest importance in connection with the family from the point of view of classification and also phylogeny. It would really seem that these structures have already disappeared in *Phreodriloides*, and that the muscular sac is not the representative of a spermatheca which has moved forwards, but has been evolved independently; further, that the posteriorly situated spermathecae in *Astacopsidrillus* are very unstable.

The *Phreodrilidae*, occupying the position usually assigned to them in the phylogenetic table, namely, as intermediate between the *Lumbriculidae* and *Tubificidae*, had possibly been derived from the Lumbriculid stem (or from the Tubificid stem) after the evolution of posteriorly situated spermathecae in that group; and one of the lines of variation along the Tubificid stem may have already been opened up before the *Phreodrilidae* left that stem, in the way indicated by the disappearance of these posteriorly situated spermathecae, as foreshadowed in *Astacopsidrillus*, and the evolution of new spermathecae after the fashion of that in *Phreodriloides*.

In conclusion, I may mention that I had the privilege of examining some specimens of *Astacopsis bicarinatus* sent from Victoria by Professor Baldwin Spencer, but was unable to detect any trace of Oligochæta in association with them.

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EXPLANATION OF PLATES XXIX.-XXXI.

at., atrium—*bld.vs.*, portion of network of bloodvessels in connection with intestine—*brn.*, brain—*cil.fn.*, ciliated funnel of spermiduct—*c.mus.*, circular muscle-fibres—*cu.*, cuticle—*cl.*, clitellum—*com.vs.*, commissural bloodvessel—*d.v.*, dorsal bloodvessel—*dvp.g.spz.*, developing spermatozoa—*ep.*, epidermis—*ex.ep.*, external epithelium of penis—*grn.*, granules—*int.ep.*, internal epithelium of penis-sac—*int.ep.*, internal epithelium of penis—*int.*, intestine—*l.mus.*, longitudinal muscle-fibres—*lm.*, lumen—*musc.*, muscle-fibres—*nph.*, nephridium—*nuc.*, nucleus—*nv.gn.*, nerve ganglion—*n.c.*, mass of nerve-cells in connection with posterior surface of brain—*ov.*, ova—*oe.*, oesophagus—*ov.sc.*, ovisac—*ovd.*, oviduct—*oes.con.*, oesophageal connective—*pn.*, penis—*pn.sc.*, penis-sac—*ph.*, pharynx—*prst.*, prostomium—*r.t.v.*, retiform mass of bloodvessels in association with the intestine—*spr.*, spermiduct—*spz.*, spermatozoa—*spth.dc.*, spermathecal duct—*sph.*, spermatophore—*sp.gld.*, spermiducal gland—*sp.*, septum—*spth.*, spermatheca—*sp.sc.*, sperm-sac—*sp.fn.*, ciliated funnel of spermiduct—*vent.n.cd.*, ventral nerve-cord—*v.v.*, ventral bloodvessel—*v₂*, divisions formed by bifurcation of dorsal bloodvessel anterior to brain.

Plate xxix.

- Fig. 1.—*Astacopsidrilus notabilis*, gen. et sp. nov. Two setæ from a latero-ventral bundle.
- Fig. 2.—Entire specimen of *A. notabilis*, as seen by transmitted light. (Drawn from a specimen stained with borax-carminé, and mounted in canada balsam).
- Fig. 3.—Transverse section of penis and penis-sac of *A. notabilis*.
- Fig. 4.—Spermiduct and spermiducal gland, etc., *A. notabilis*, reconstructed from serial sections.
- Fig. 5.—Transverse section of spermathecal duct of *A. notabilis*.
- Fig. 6.—Transverse section of spermathecal duct of *A. fusiformis*, gen. et sp. nov. N.B.—Circular musculature much exaggerated.

Fig.7.—Longitudinal vertical section through the genital region of *A. fusiformis*.

Fig.8.—Transverse section through spermiducal gland of *A. notabilis*.

Fig.9.—Entire individual of *A. fusiformis*.

Plate xxx.

Fig.10.—Spermiduct, spermiducal gland, etc., of *A. fusiformis* reconstructed from serial sections.

Fig.11.—Spermatheca of *A. fusiformis*, containing spermatophores.

Fig.12.—Horizontal section through anterior extremity of an individual of *A. notabilis*.

Fig.13.—Mass of developing ova of *A. notabilis*.

Fig.14.—Cells of the epithelium of spermatheca of *A. notabilis* showing their granular nature.

Fig.15.—Blood-vascular system of *A. notabilis*, reconstructed in part from serial sections, in part from entire specimens mounted in canada balsam.

Plate xxxi.

Figs.16, 17.—Longitudinal sections through the genital segments of *A. notabilis*.